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CAN AUTHORITATIVE STUDIES BE TRUSTED?

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CAN AUTHORITATIVE STUDIES BE TRUSTED?

Can authoritative studies be trusted? Not always. Let me illustrate with one example, unfortunately among many I have encountered.

A study known as Strat-X, published in 1967, was probably the broadest and most influential study ever conducted on strategic options. Its results have been used or quoted countless times over the years, the latest instance being MX Missile Basing, a study conducted last year by the Congressional Office of Technology Assessment (OTA).

In the course of examining the possibility of ship-basing the MX, I found mathematical errors in Strat-X, one of which is quite significant. It has nothing to do with the assumptions, only with a faulty understanding of the ship-trailing process being modeled.

A ship starts out trailed on an n-day patrol. It can break trail, with probability p_b , only in bad weather. The daily probability of bad weather, assumed independent from day to day, is p . Once trail is broken, it is not reacquired. With these assumptions, Strat-X concluded that the average number of days N the ship is free of trail is given by:

$N = \text{Probability trail is broken } (p_b) \text{ times the average number of days after bad weather is encountered.}$

This is incorrect. The correct result is:

$N = \text{Average number of days after bad weather is encountered and trail is broken,}$

which is a longer period. The faulty equation leads to:

$$N = p_b \left\{ n - \frac{1-p}{p} [1 - (1-p)^n] \right\} ,$$

whereas the correct equation leads to:

$$N = n - \frac{1 - pp_b}{pp_b} [1 - (1 - pp_b)^n] . *$$

* This result is derived as follows. The probability of shaking the trailer off on the k^{th} day is $(1 - pp_b)^{k-1} pp_b$. This action results in $n - k + 1$ days free of trail. Thus:

$$N = \sum_{k=1}^n (n - k + 1)(1 - pp_b)^{k-1} pp_b .$$

The sum is easily carried out using the following geometric progression results:

$$\sum_{k=0}^n x^k = (1 - x^{n+1}) / (1 - x)$$

$$\sum_{k=0}^n kx^k = x \frac{d}{dx} \sum_{k=0}^n x^k = x(1 - x)^{-2} [1 - x^n - n(1 - x)x^n] .$$

To convince yourself that the correct result cannot split p and p_b but must depend on their product only, observe that the significant event is not bad weather alone, but bad weather followed by broken trail.

Assuming $p = .05$, $p_b = .5$, and a 60-day patrol, as in the OTA study, the correct result is 30 days free of trail. The result yielded by the wrong formula was wrongly applied in the OTA study, which gave the result as being only 21 days free of trail, thus shortchanging the shipbasing concept even further. The longer the patrol time, the more the error is compounded. For a 90-day patrol, the incorrect formula yields only 36 days of freedom from trail, whereas the correct formula yields 55 days. Also, the lower p_b is, the larger the error. For $p_b = .25$ and $n = 90$, the wrong formula yields 18 days free of trail, whereas the correct formula yields 36 days--twice as many.

Thus, the correct fraction of time the ship is free of trail is usually much higher than that reported in Strat-X. It is between 41 and 54 percent higher using the OTA sample inputs, given patrol times between 60 and 90 days. It is 100 percent higher if the break-trail probability is halved.

This Strat-X error is a simple example of averages being taken too soon, a frequent malady of expected-value approaches. In this case, it takes little extra effort to get the right answer. Further, a more detailed Markov-chain trailing model that also includes trail reacquisition is not difficult to build.

In addition, the Strat-X formula for the required number of Soviet trailing ships, duly retranscribed and used in the OTA study, is not explained, could not be rederived, and does not make sense for certain values of the parameters. A correct expression is also not difficult to find.

Two related morals emerge:

1. In reviewing studies, we should pay more attention to mathematical details and search for subtle errors in modeling (or even gross errors in arithmetic). This can be as important as checking the soundness of the assumptions and the reliability or relevance of the data.
2. We should not uncritically lift results from published studies, whatever the aura of authority these studies have acquired over the years. Follow-the-leader is not a game for serious analysts.

The standard excuses, such as "The final conclusions don't change," or "The uncertainties in the assumptions drown out the errors," are unacceptable. If the conclusions are insensitive to significant errors

in calculation, then detailed numerical analysis was probably not needed in the first place and should not have been performed; analysis for analysis' sake must be avoided. If the assumptions carry large uncertainties, all the more reason why the sensitivity of the final results to changes in the assumptions must be carefully analyzed; the quantification of this sensitivity then becomes the prime contribution of analysis, and an important one.

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